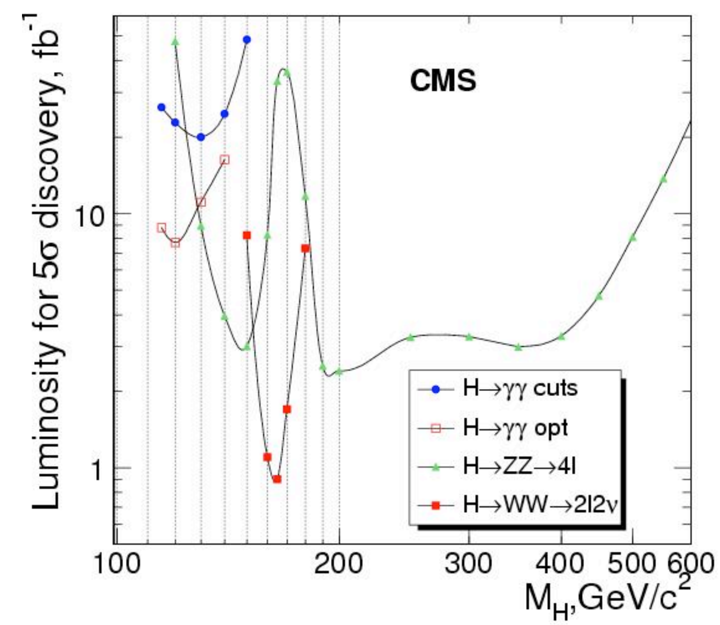
CMS Preparations for Early LHC Physics

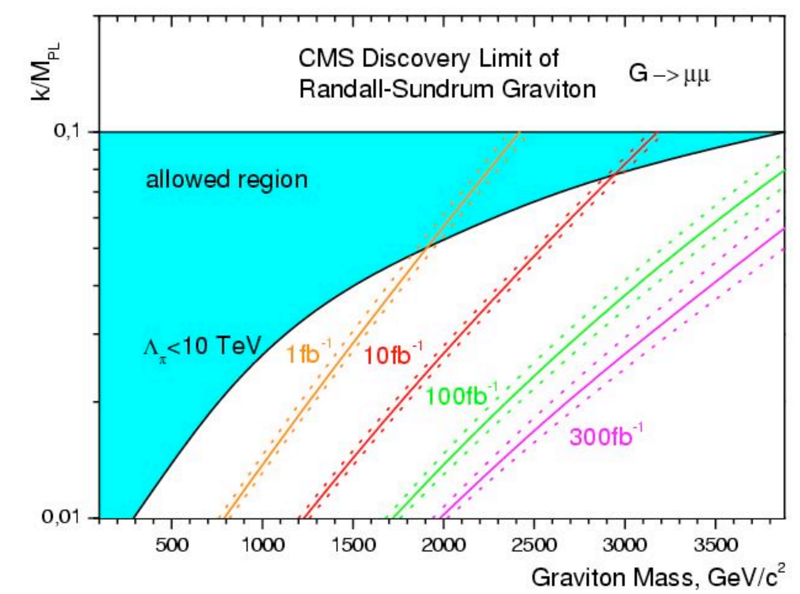
Joint Theory-CMS Seminar
May 31, 2007

Kevin Burkett (Fermilab)

Introduction

- LHC is built to discover new physics
- Long list of possible scenarios
  - Higgs
  - SUSY
  - Extra Dimensions, Z′
  - Substructure, contact interactions
  - Something “as yet unthought of”





- First, have to get the detector running and make the measurements that form the foundation on which we can look for new physics

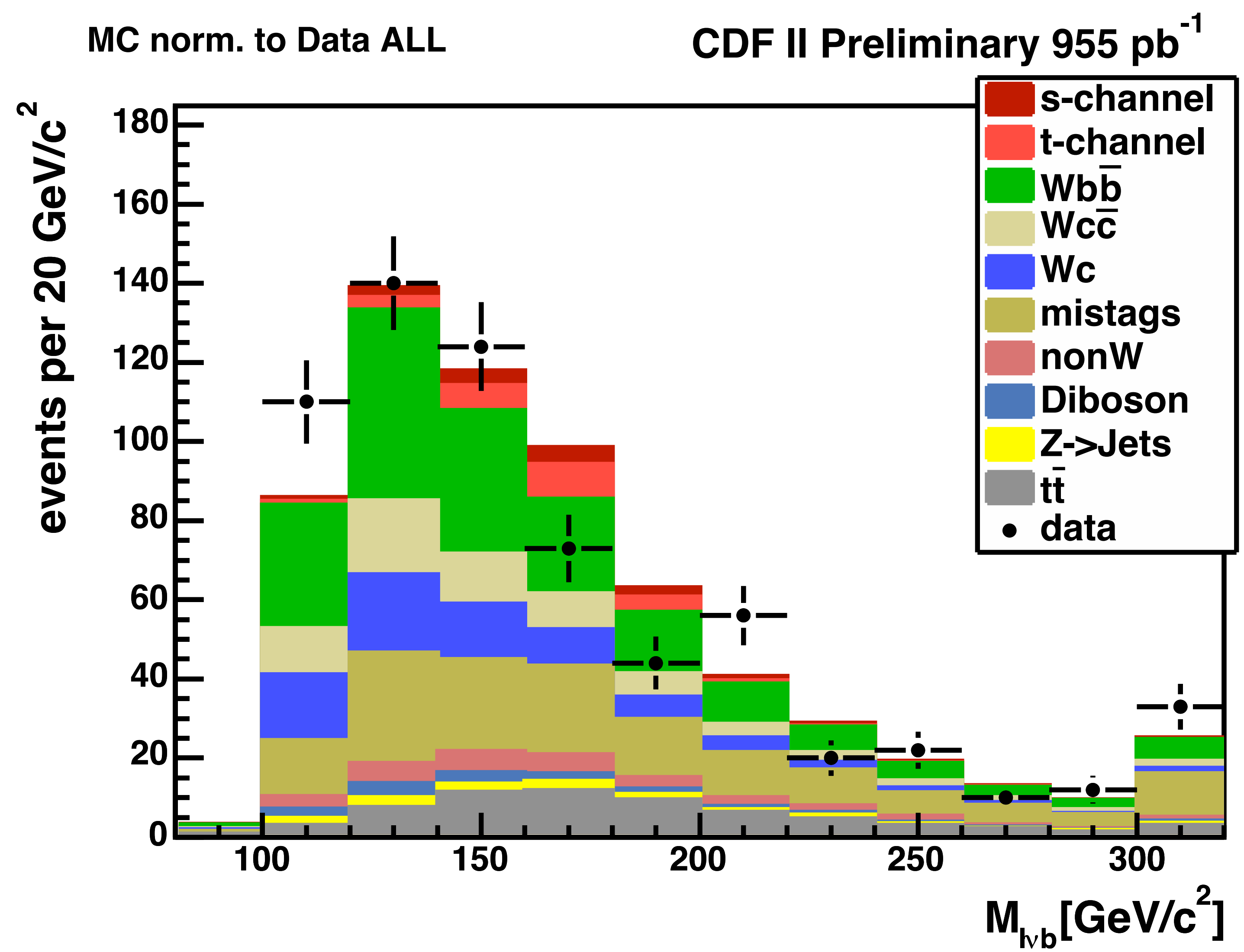
Looking for something new

Finding a signal for new physics means understanding all the SM backgrounds

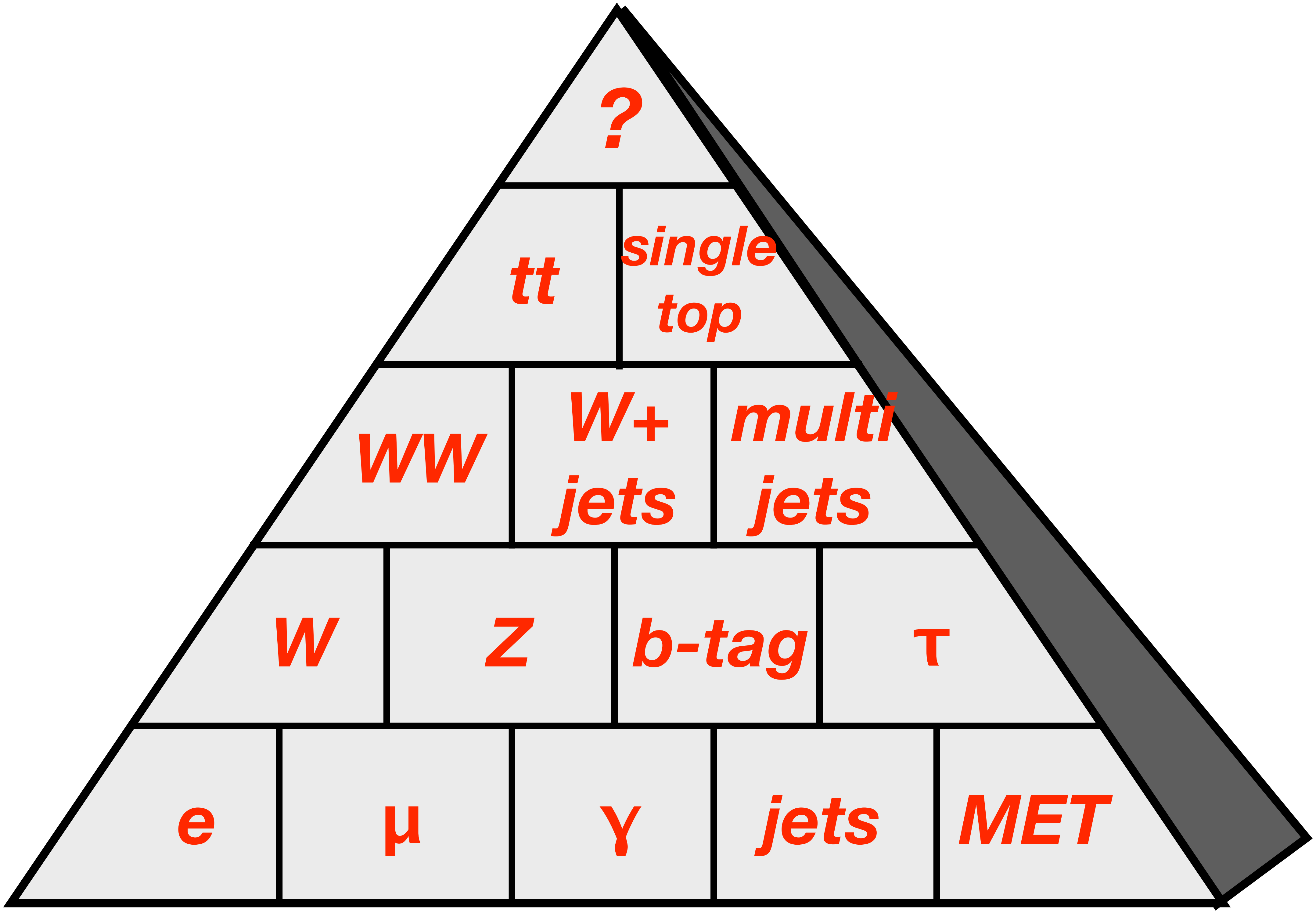
As an example...

Single Top

- Long list of backgrounds
- Each background is made up of many pieces as well
- CMS has to start back at the beginning



Looking for something new

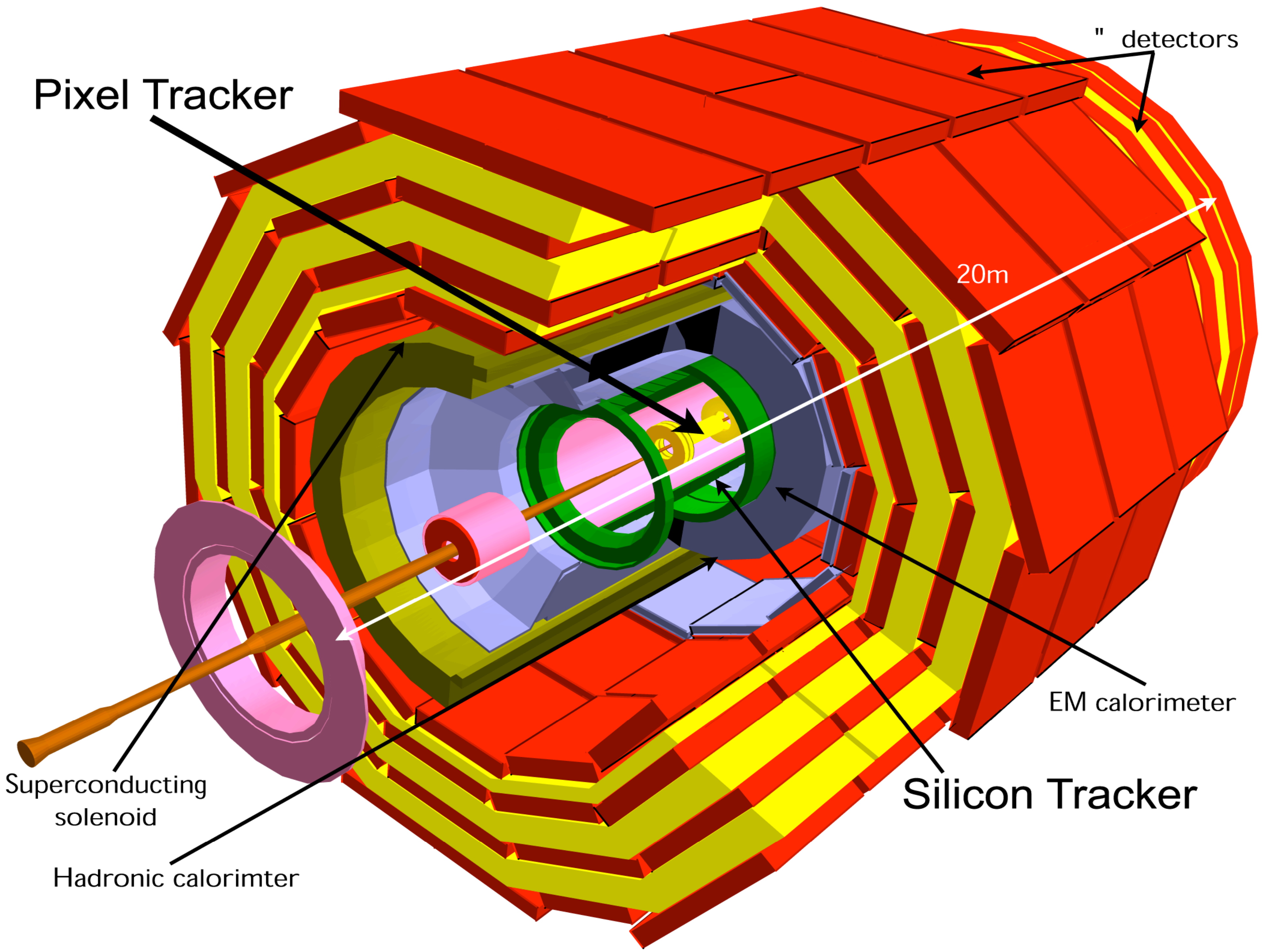


Getting CMS Ready for Physics

Since we don't know when/where new physics might appear, CMS needs to be ready as early as possible

- Have to calibrate and align the detector
- At the same time, commission trigger and DAQ
- General strategy:
  - Prepare as much as possible beforehand, using cosmic rays, test beam, etc.
  - "Rediscover the Standard Model"
  - Use the clear, well-known signals of SM to commission the detector

CMS Detector



Data Samples

- Ignore the exact date of the LHC turn-on or the speed of the luminosity ramp-up
- Today consider four data samples
  1. Early data running: $< 10\ pb^{-1}$

     Initial luminosity starting ~ $L=10^{28}$

     Detector alignment, calibration from cosmics, sources, MC
  2. $10\ pb^{-1}$
  3. $100\ pb^{-1}$

     First data-driven alignment, calibration being applied
  4. $1\ fb^{-1}$ (~6 months running at $L=10^{32}$)
- For each data sample:

  What Standard Model physics can we measure?

  How can we use the data to improve detector performance?

Standard Model Rates

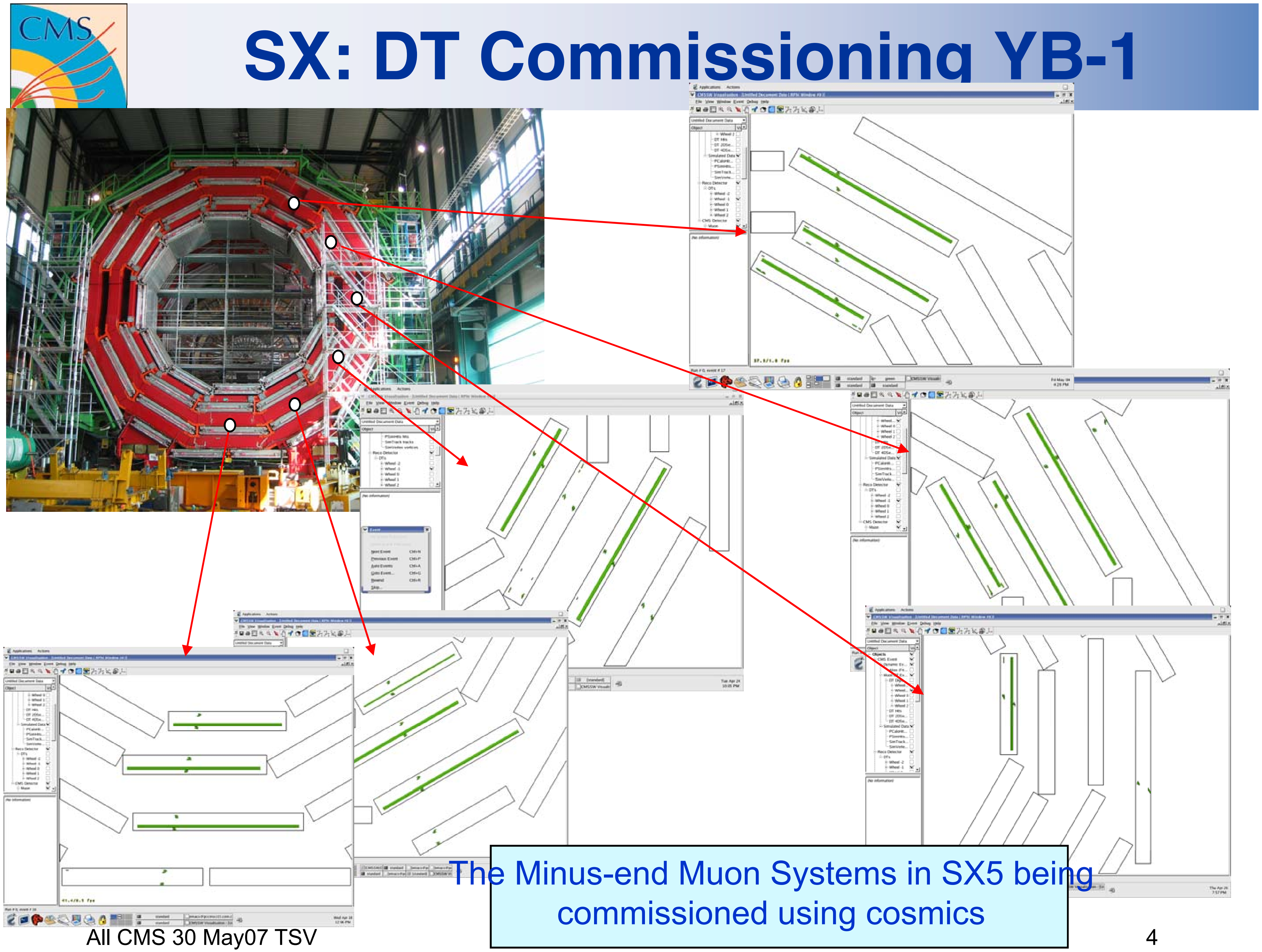
Approximate event rates for different samples

(making a few reasonable assumptions about efficiency)

Channel	10 pb^{-1}	100 pb^{-1}	1 fb^{-1}
$W \rightarrow \mu\nu$	10^5	10^6	10^7
$Z \rightarrow \mu\mu$	10^4	10^5	10^6
$tt \rightarrow \mu\nu X$	10^2	10^3	10^4

Comparable statistics to Tevatron after 100 pb^{-1}

Preparing before beam



- J. Virdee 5/30/07 - All CMS Meeting

Early Physics with Tracker

One of the the earliest results to come from CMS could involve simple distributions of tracks

1st paper from CDF

VOLUME 61, NUMBER 16 PHYSICAL REVIEW LETTERS 17 OCTOBER 1988

Transverse-Momentum Distributions of Charged Particles Produced in $\bar{p}p$ Interactions at $\sqrt{s} = 630$ and 1800 GeV

Measurements of inclusive transverse-momentum spectra for charged particles produced in proton-antiproton collisions at $\sqrt{s}$ of 630 and 1800 GeV are presented and compared with data taken at lower energies.

Likely one of the 1st papers from CMS

Charged particle multiplicity in pp collisions at $\sqrt{s} = 14$ TeV

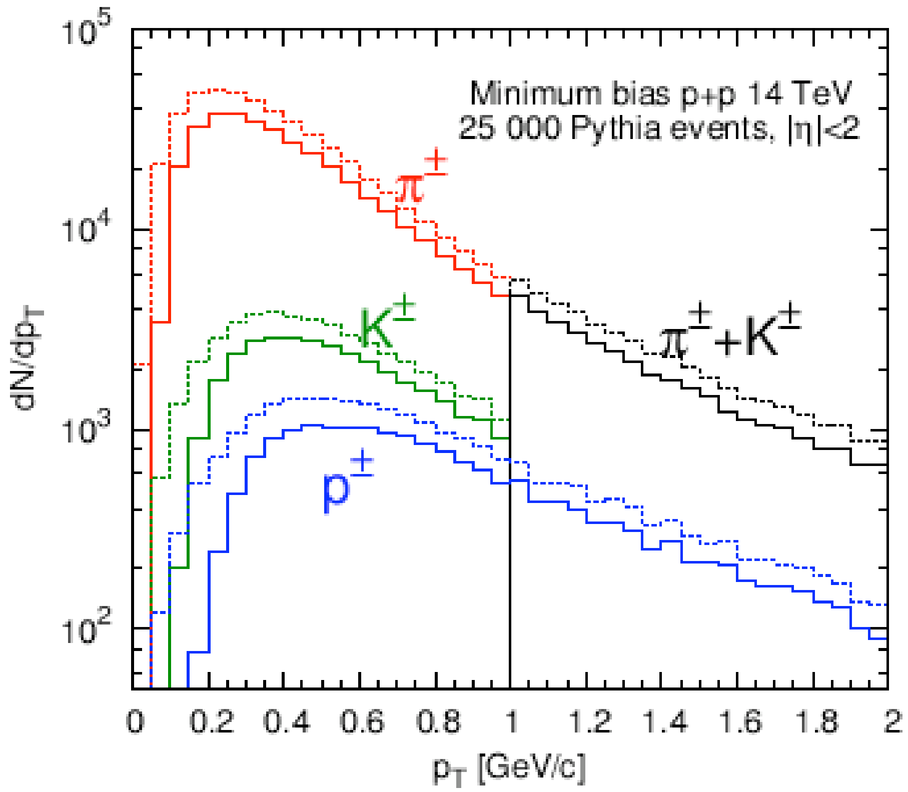
We report on a measurement of the mean charged particle multiplicity in minimum bias events, produced in the central region $|\eta| < 1$, at the LHC in pp collisions with $\sqrt{s} = 14$ TeV, and recorded in the CMS experiment at CERN. The events have been selected by a minimum bias trigger, the charged tracks reconstructed in the silicon tracker and in the muon chambers. The track density is compared to the results of Monte Carlo programs and it is observed that all models fail dramatically to describe the data.

- A. De Roeck

Physics with Early Data

Early data is good for both physics and for starting data-driven detector calibrations

- Min bias measurements to ~~understand~~ tune underlying event

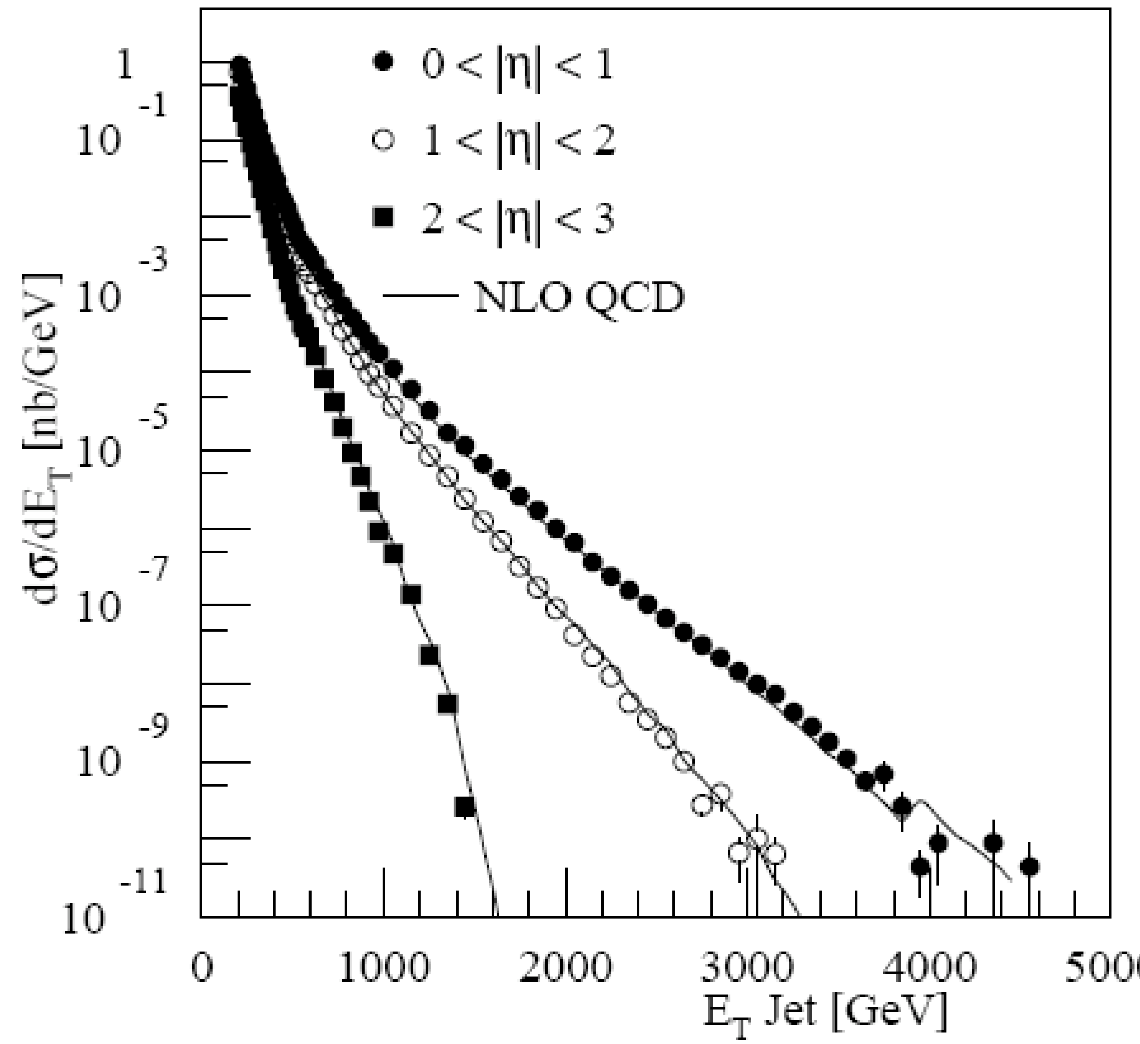


- Improve alignment with high P_T tracks
- Refine calorimeter calibrations
  - Zero-bias triggers used to measure noise
  - Isolated tracks compared to test beam data for HCAL
  - $\pi^0,\eta\rightarrow\gamma\gamma$ for in situ ECAL calibration

Early Physics with Jets

Huge jet cross-section, many orders above Tevatron

Another early CMS paper?



Measurement of inclusive jet cross section in pp collisions at 14 TeV

We present results from the measurement of the inclusive jet cross section for jet transverse energies from 100 to 1500 GeV in the pseudorapidity range $0.1 < |\eta| < 1.4$. The results are based on 18 pb^{-1} of data collected by the CMS Collaboration at the Large Hadron Collider at CERN. The data are consistent with previously published results. The data are also consistent with QCD predictions given the flexibility allowed from current knowledge of the proton parton distributions.

- K. Lassila-Perini

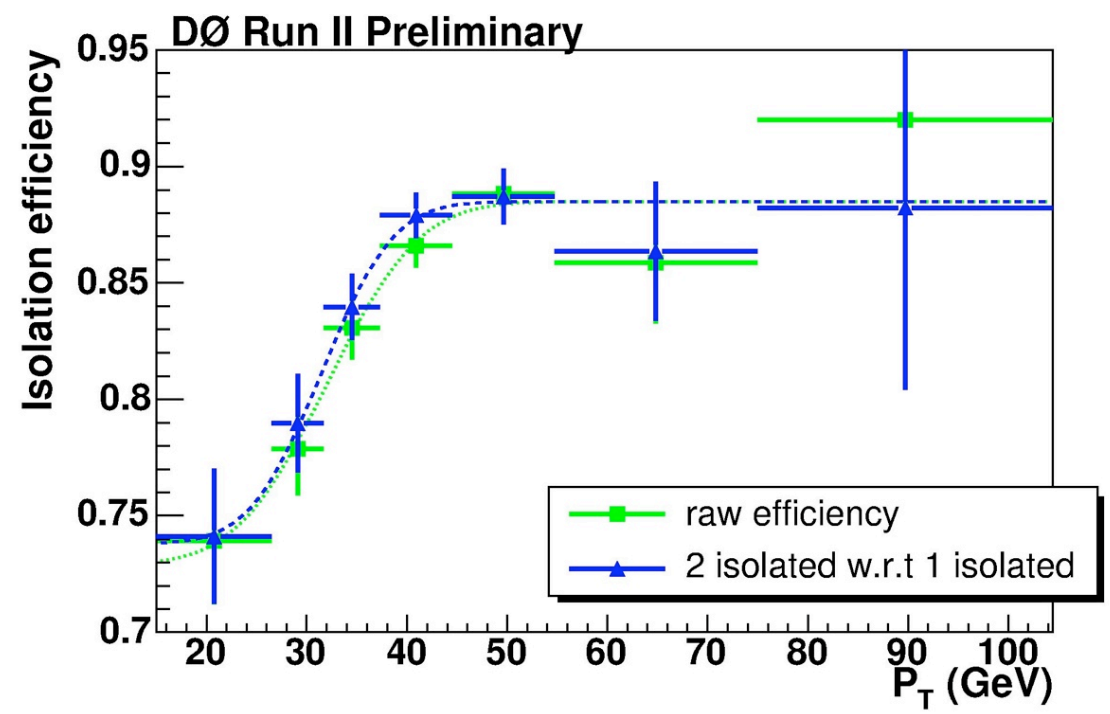
Physics with ~10 pb^{-1}

- Expected numbers of events:

  70k $W \to l\nu$, 10k $Z \to l^+l^-$

  50 dilepton ttbar, ~350 lepton+jets ttbar

- Measure W and Z production cross-section
  - Understand efficiency (esp. isolation) <u>from data</u>
  - Understand bkgd <u>from data</u>

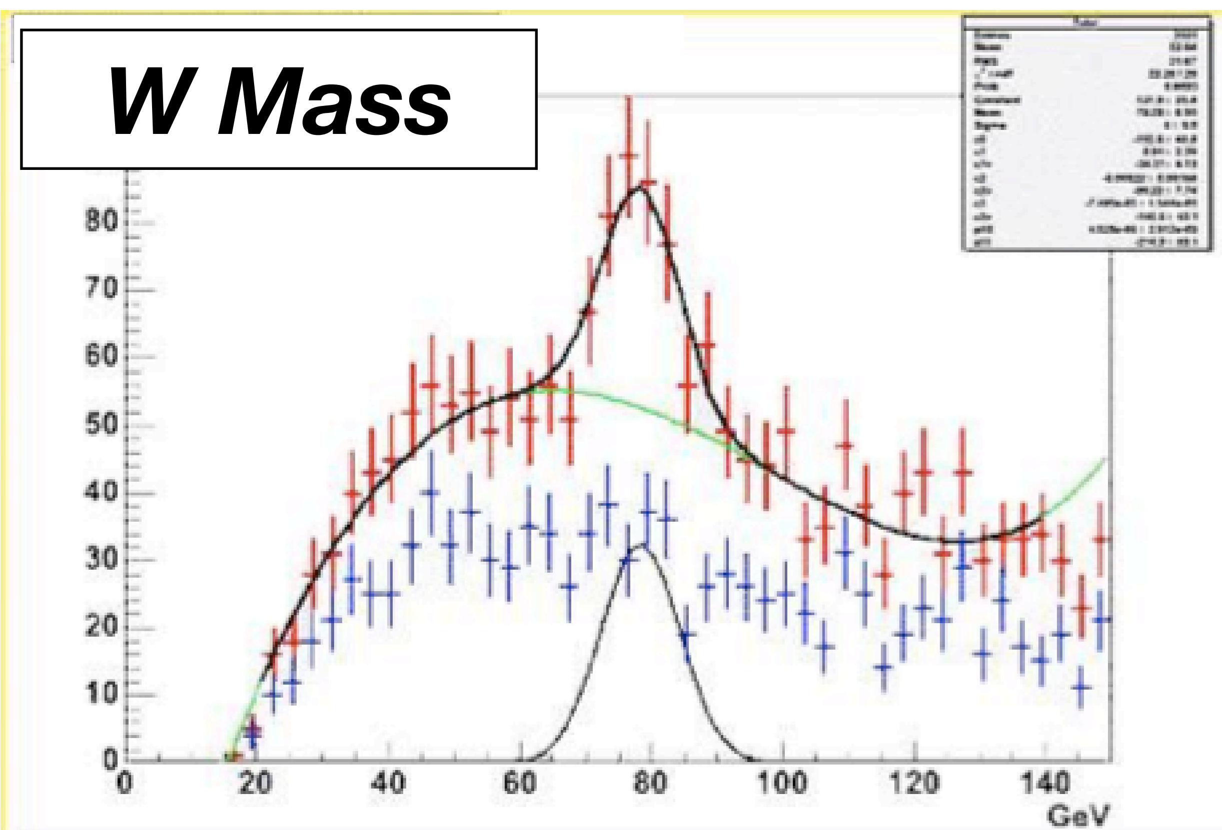


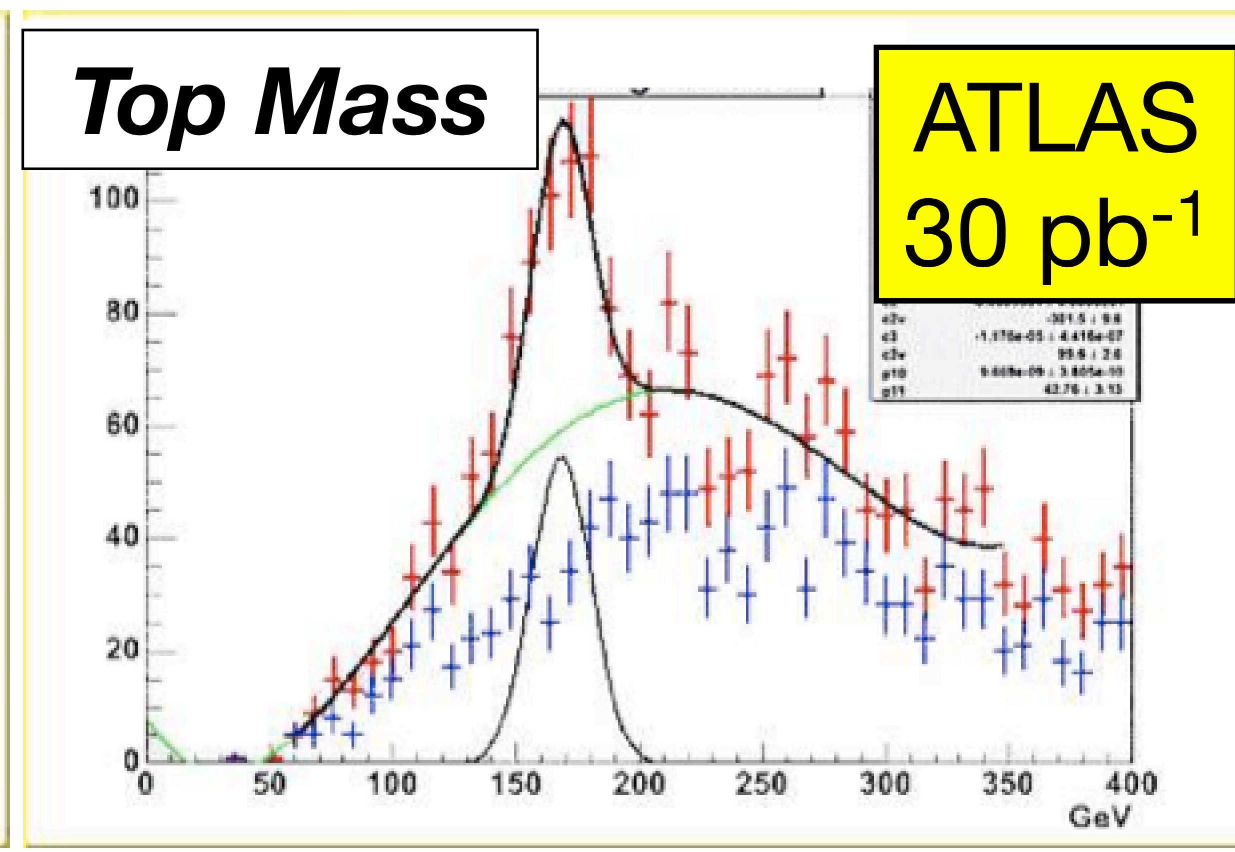
- Observe top pair production
  - First complex event topology to be reconstructed
  - Probably requires 20-30 pb^{-1}

Observation of top at 14 TeV

Simple reconstruction without b-tagging

- Use semi-leptonic top events with exactly 4 jets
- Select 3 highest ΣP_T jets
- Two jets with highest ΣP_T are W
- Background from W+4jets



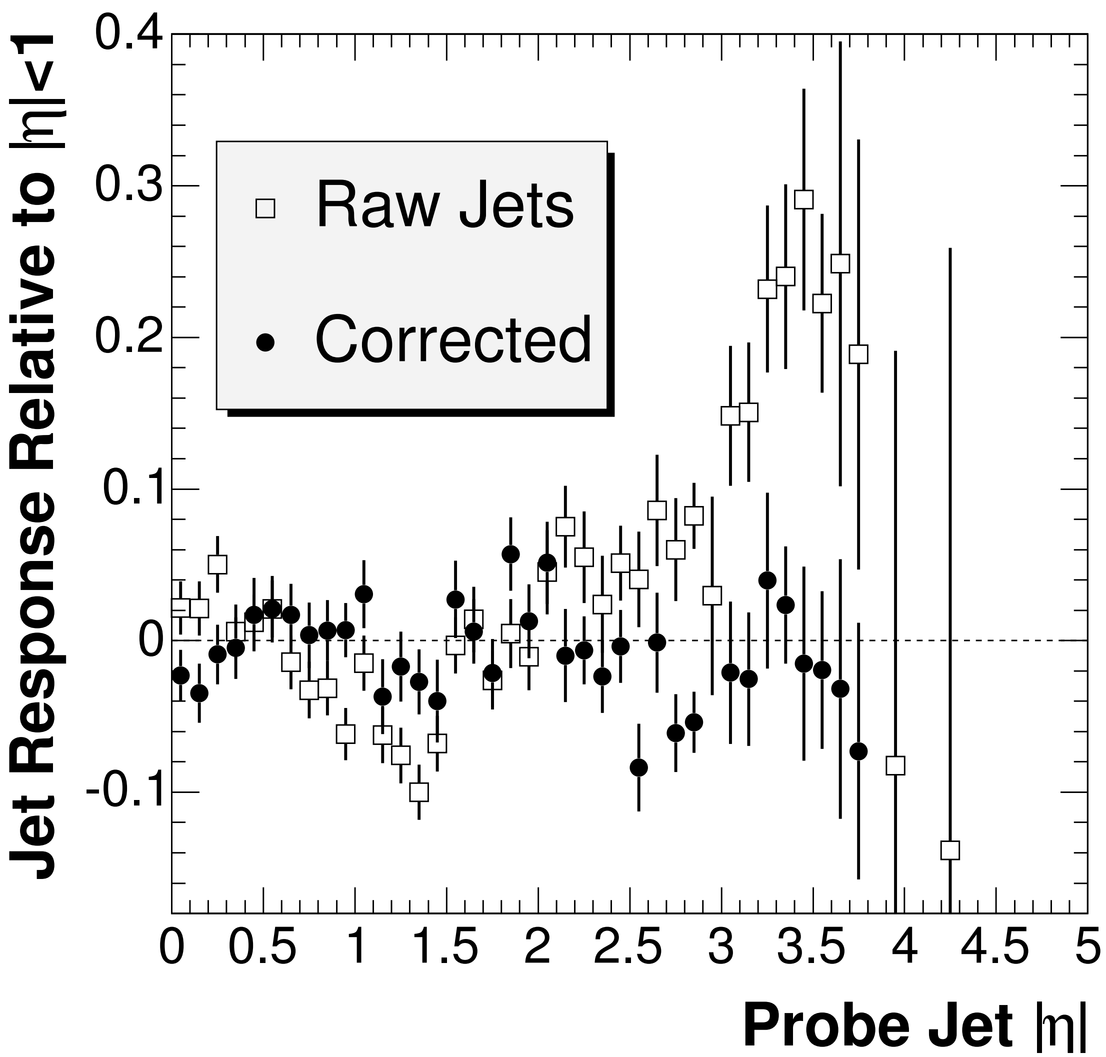


Details in ATLAS note atl-phys-pub-2005-024

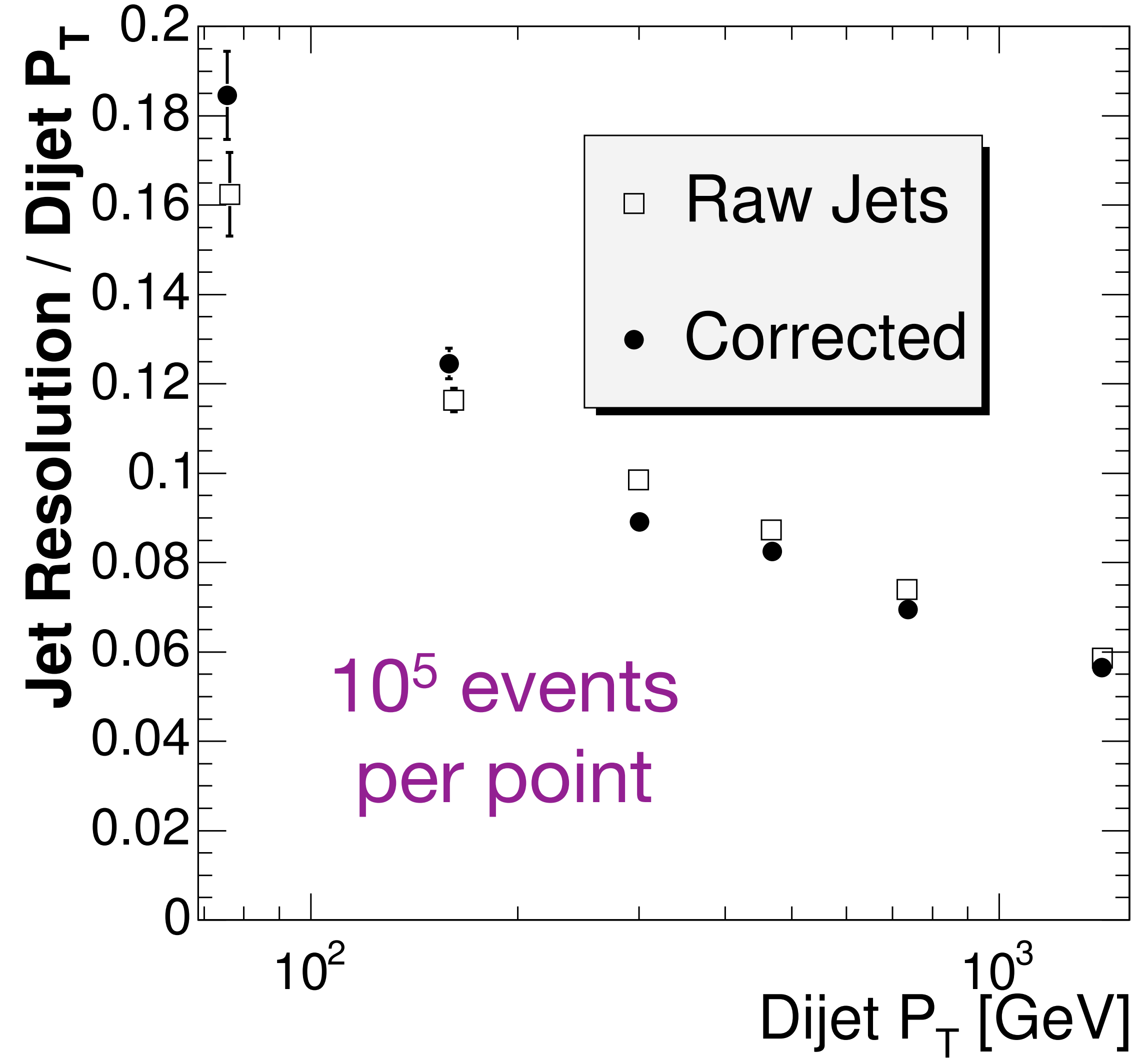
Jet Calibrations from Data

Initial calibrations from sources, test beam, and MC

- Can be refined with very early data
- To go further, use dijet and photon-jet balancing



MC corrections flatten response vs. eta

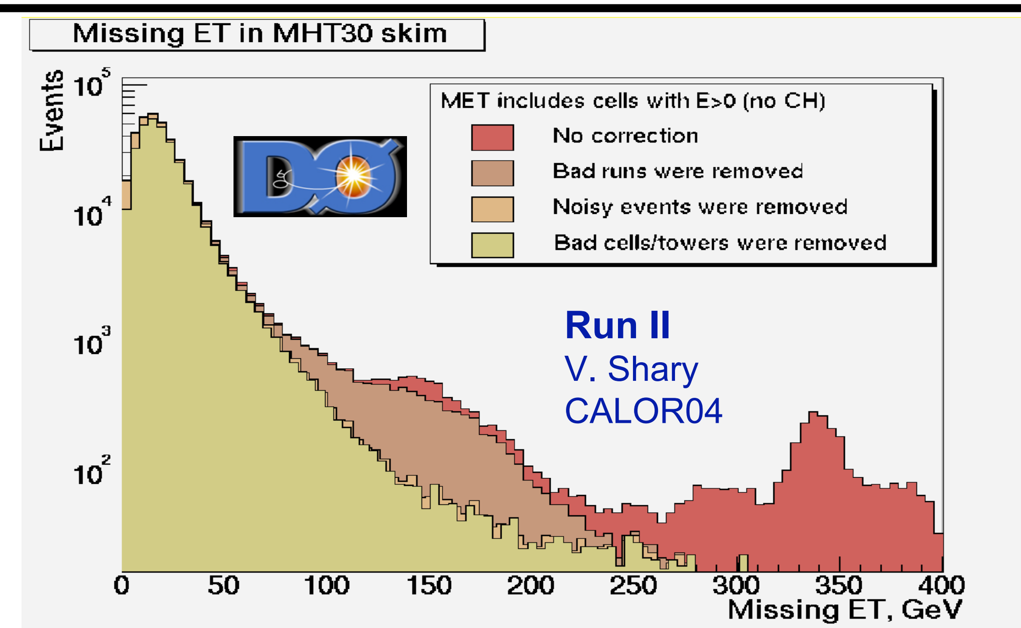


Missing E_T

Two parts to Missing E_T:

Understanding high MET tails

Resolution on real MET

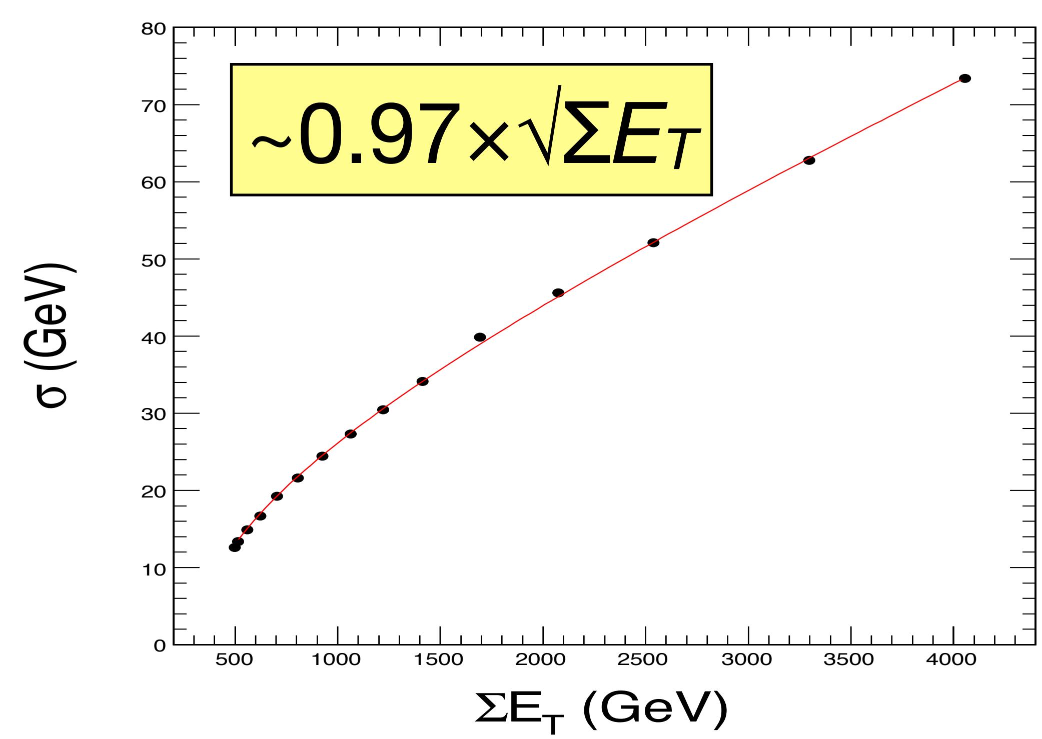


Cleaning up tails:

- Some clean up without beam from calibrations, etc.
- Use data to understand beam backgrounds
- Tools taken from Tevatron, but need study at LHC

Measure MET Resolution

- Effect of pile-up?
- Improvement w/jet corrections



Evolution of the Trigger

- At turn-on Level 1 trigger will be wide open
  - Low Sum E_T in calorimeter or any muon
- $L=10^{28\text{-}29}$ start adding simple triggers
  - Calorimeter - low E_T electron (5 GeV) or jet (10 GeV)
  - Low P_T muon (3 GeV)
  - Use High Level Trigger to control rate to tape
- Two parallel strategies as luminosity, trigger rates rise:
  - Keep lower thresholds on some triggers by adding conditions
    - Isolation, Had/EM for electrons
    - Isolation, extra quality cuts on muon
  - Raise thresholds on unrestricted triggers
    - No added conditions on these triggers

Physics with ~100 pb^{-1}

- Expected numbers of events:

  1M $W \to l\nu$, 100k $Z \to l^+l^-$

  400 dilepton ttbar, 2500 lepton+jets ttbar

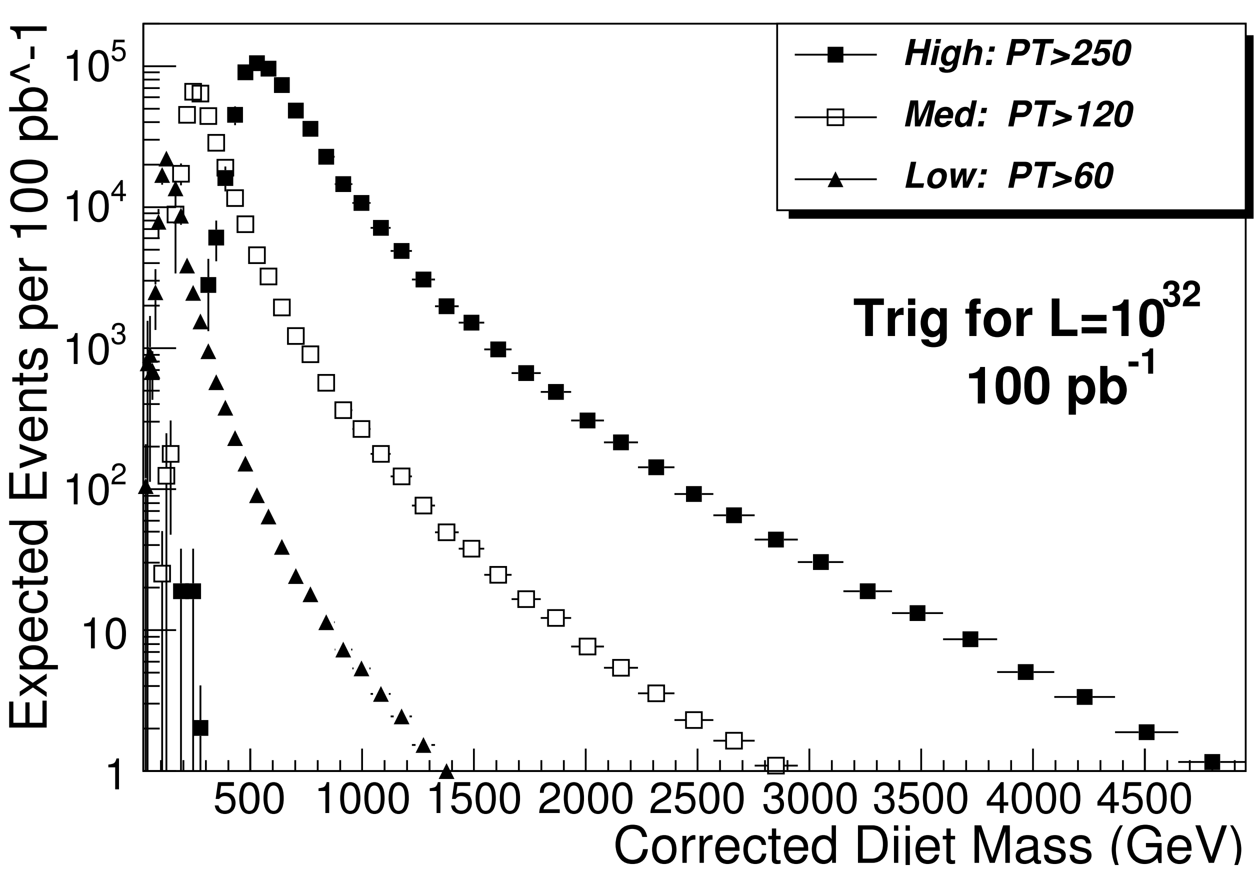
  1000 Jets $P_T > 1$ TeV

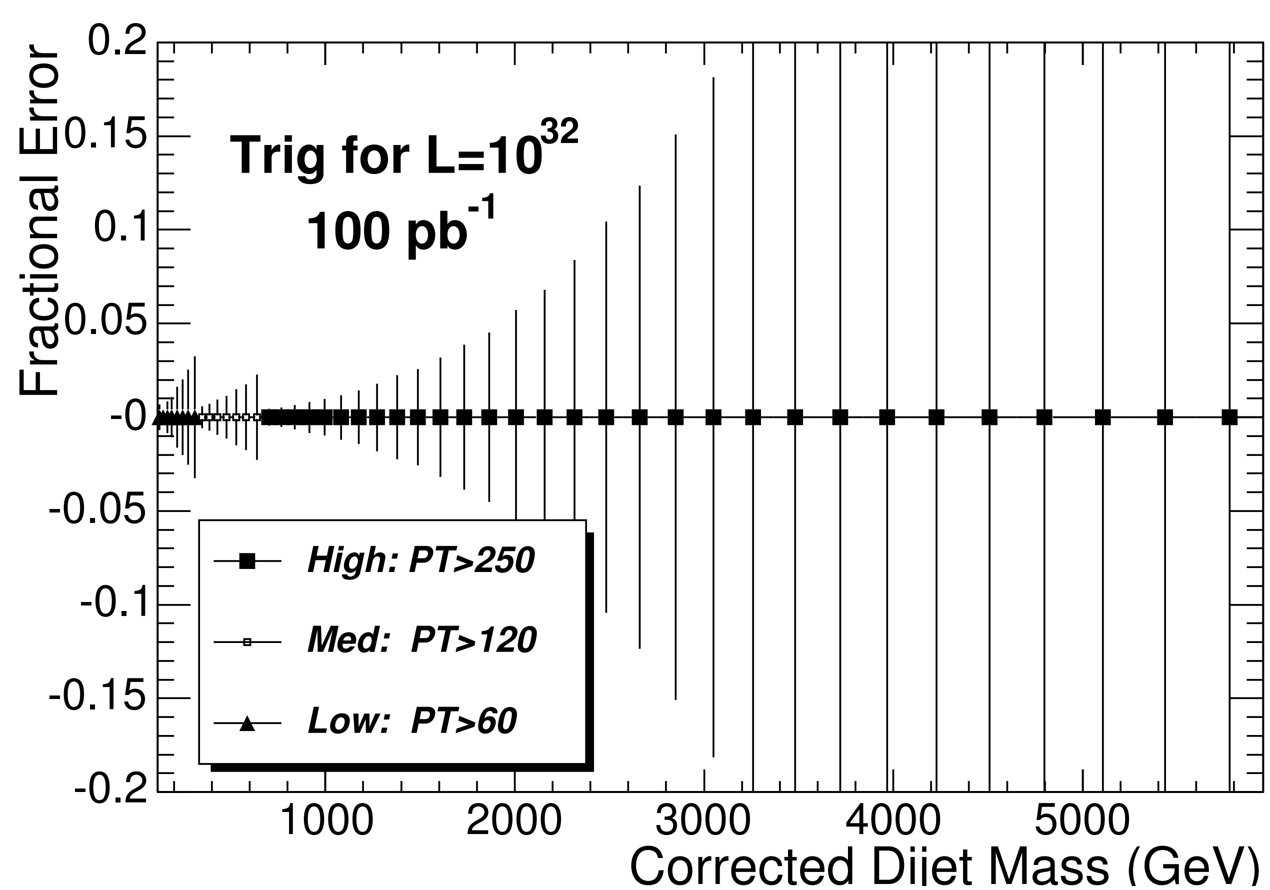
- Dijet masses up to ~5 TeV
- First W and Z with taus
- First real top measurements
  - Measure top cross-section
  - Measure top mass
  - Use top sample to verify JES, b-tagging efficiency

Dijet Analysis with 100 pb^{-1}

- Trigger strategy carefully defined to match thresholds, prescales to avoid gaps in sensitivity
  - Lowest threshold triggers to match with Tevatron
- Use data-driven jet corrections

Statistical precision < 3% for dijet masses < ~1.5TeV



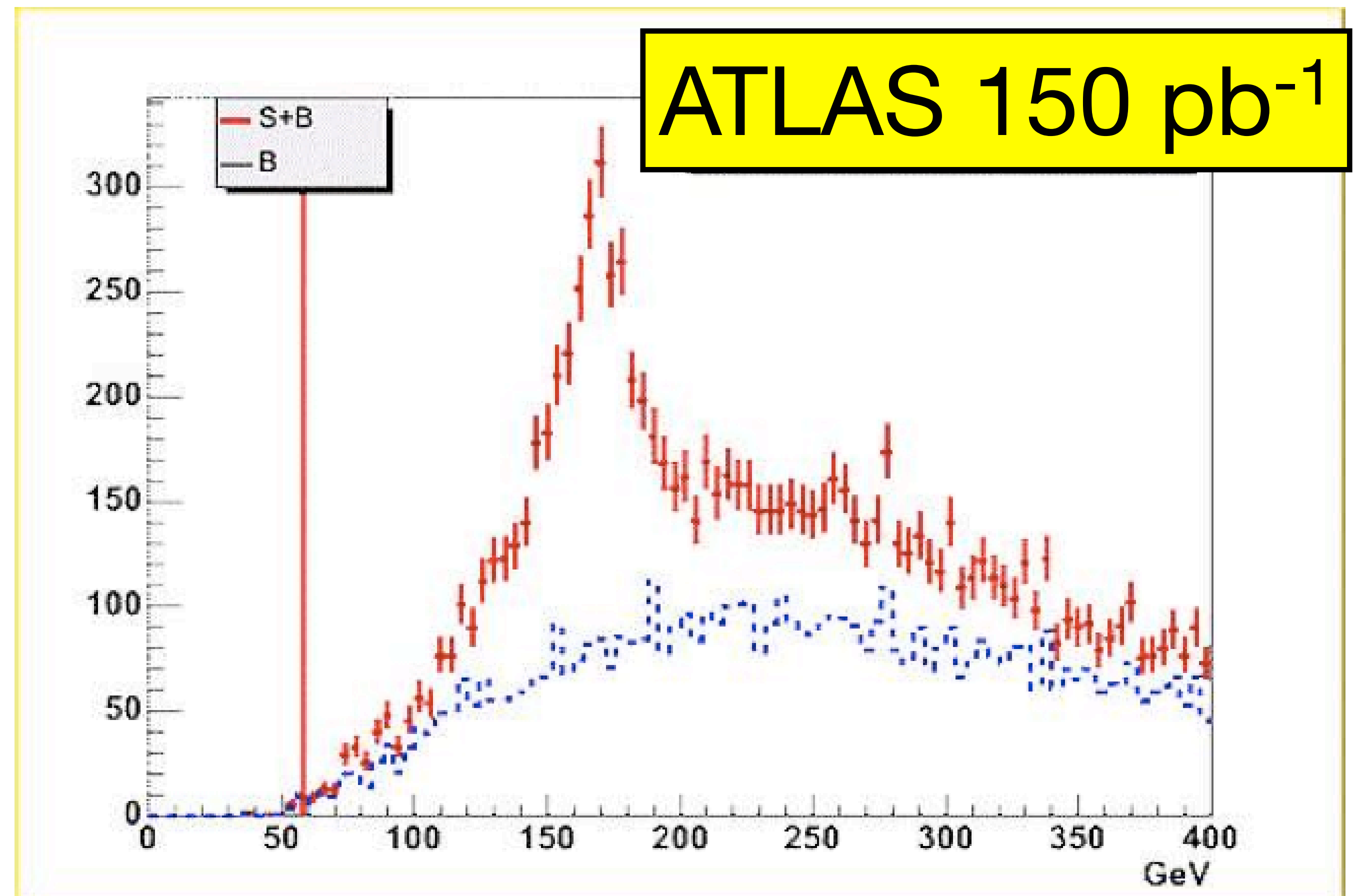


Top cross-section with ~100 pb^{-1}

Same reconstruction as before in lepton+jets events

- Invariant mass of 3 highest ΣP_T jets
- No b-tags or kinematic fit

Good statistical precision, but systematics (especially on mass) may still be large

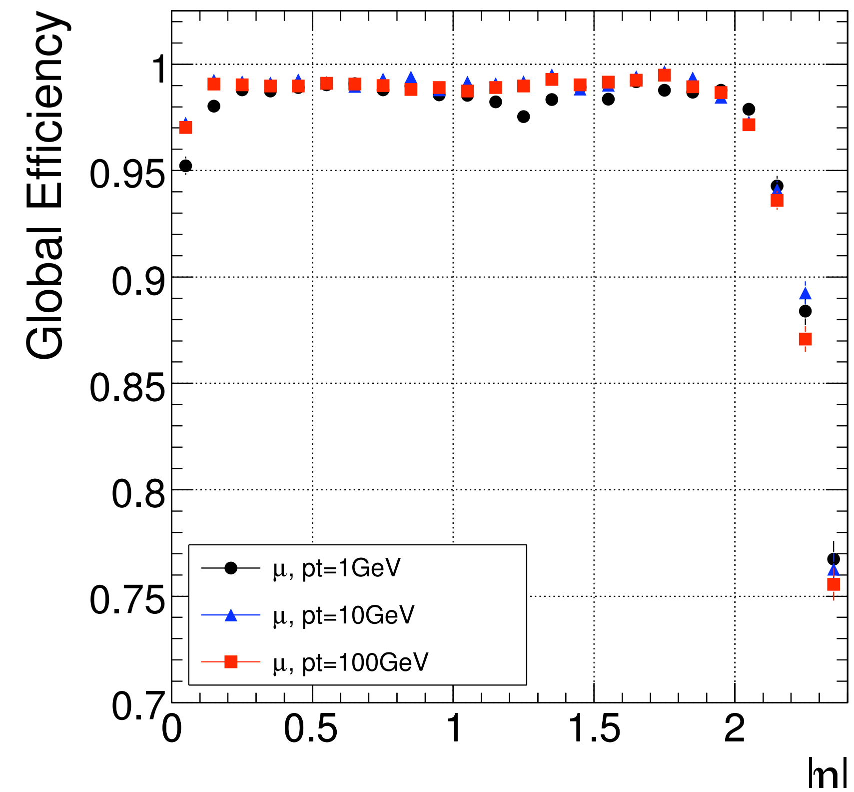


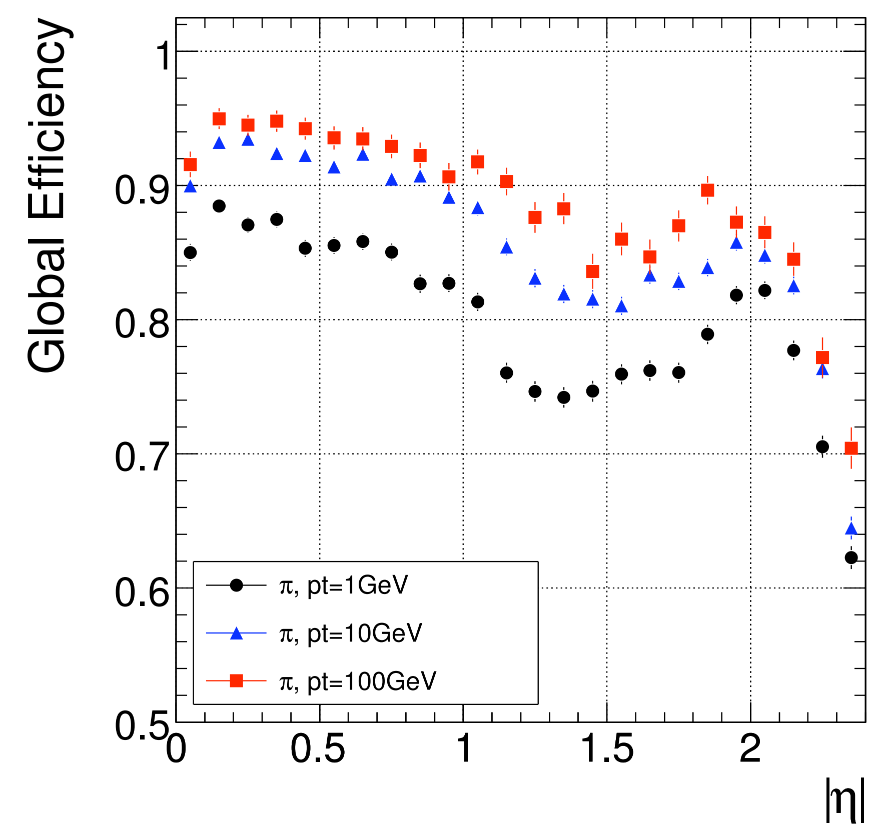
- Sample should be large enough, with good purity, that the b-tagging efficiency or jet energy scale can be cross-checked in the data

Tracker Alignment with Data

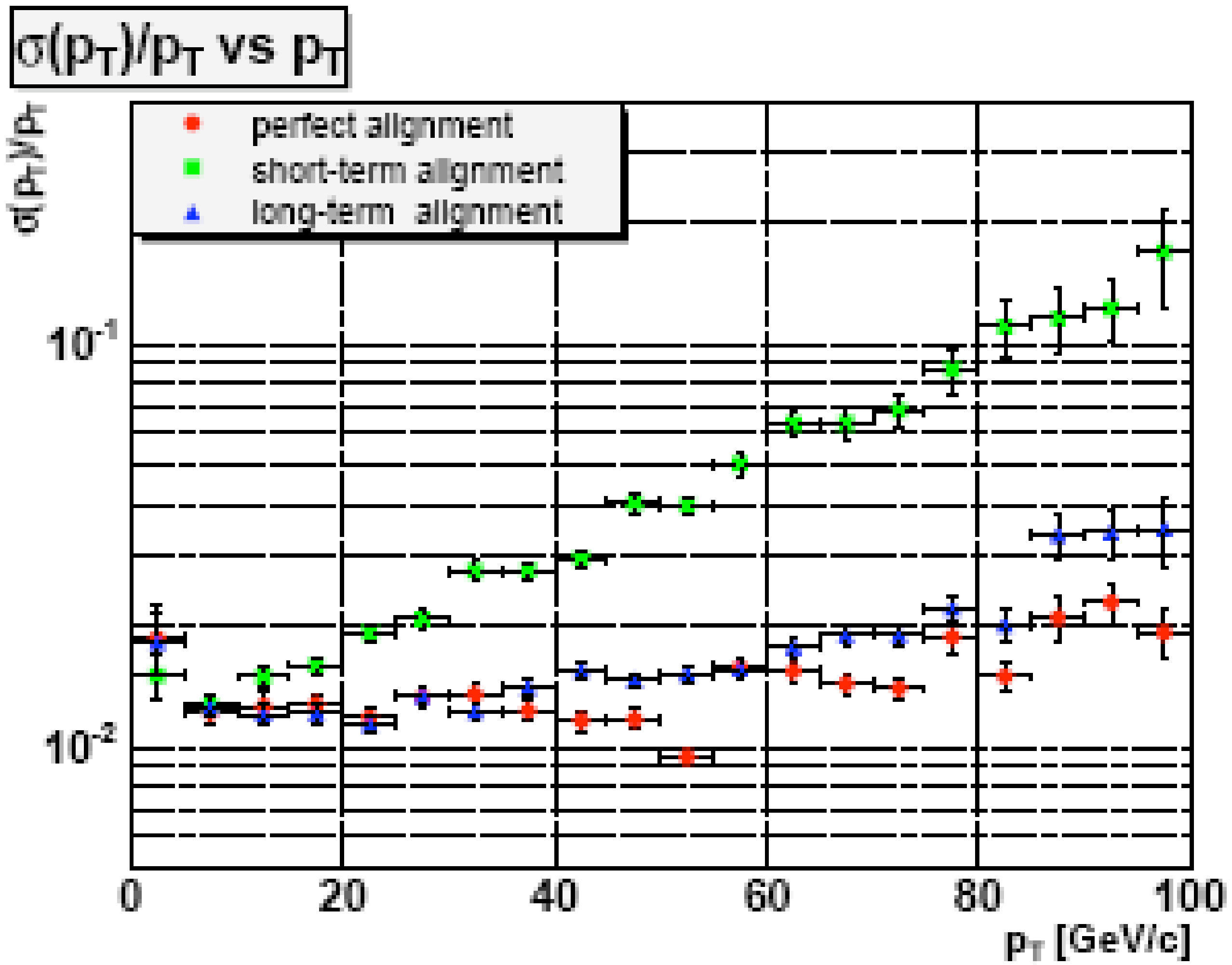
Most important issue in getting optimal performance from the tracker will be alignment

- Efficiency expected to be high
  - mostly unaffected by misalignment
- Early alignment from survey, cosmic rays, beam gas
- Need high P_T muons from W and Z to improve alignment,
  - ~100k $Z \to \mu\mu$ in 100 pb^{-1}

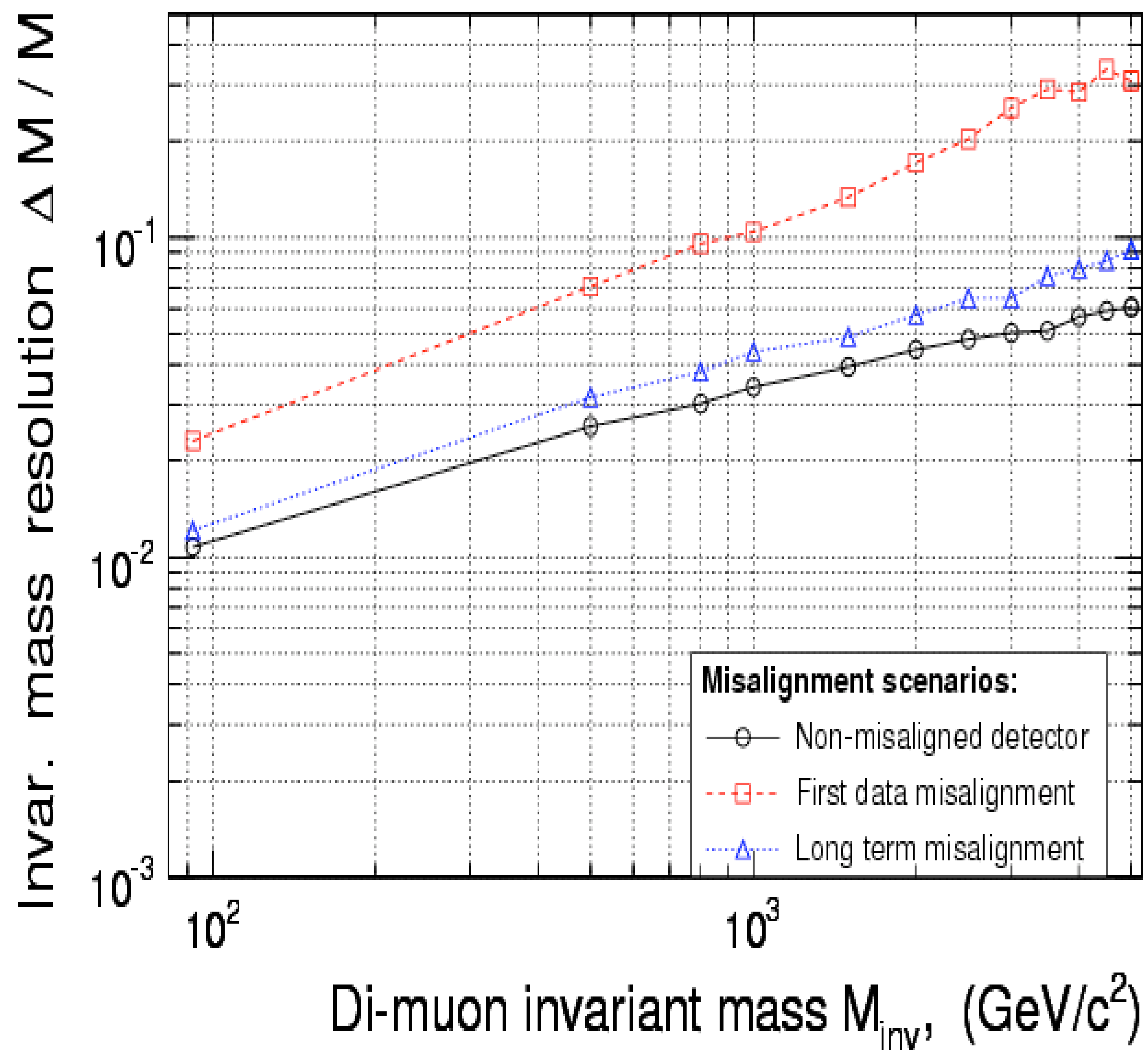




Effect of Tracker Alignment



Short term: 0.1-1 fb^{-1}
Long term: > 1 fb^{-1}



- Early misalignment affects momentum, mass resolution
- Above 1 TeV, muon system becomes important

Physics with ~1 fb^{-1}

- Expected numbers of events:

  10M $W \to l\nu$, 1M $Z \to l^+l^-$

  2000 dilepton ttbar, 12000 lepton+jets ttbar

  10000 Jets P_T>1 TeV

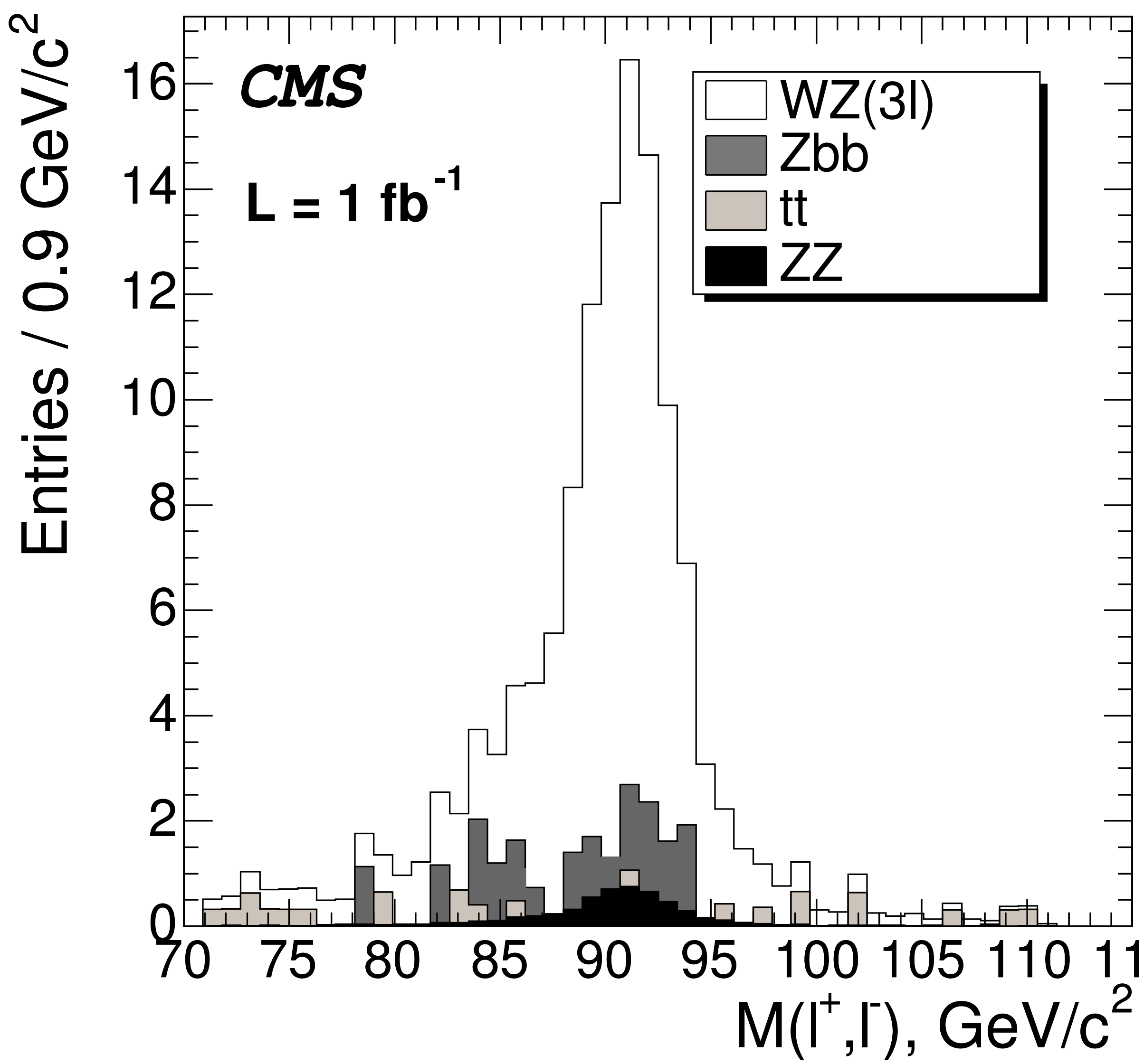
- Extending dijet spectrum up to ~6 TeV
- W+jets and Z+jets
- Dibosons
- First real top measurements
  - Observe single top, fully hadronic top decays
  - Use top sample to measure JES, b-tagging efficiency

Diboson Production with ~1 fb^{-1}

- Look for WZ→3 leptons (e or μ)
  - Reject events with second Z candidate
  - Reject events with jets above 25 GeV

Expected Events in 1 fb^{-1}

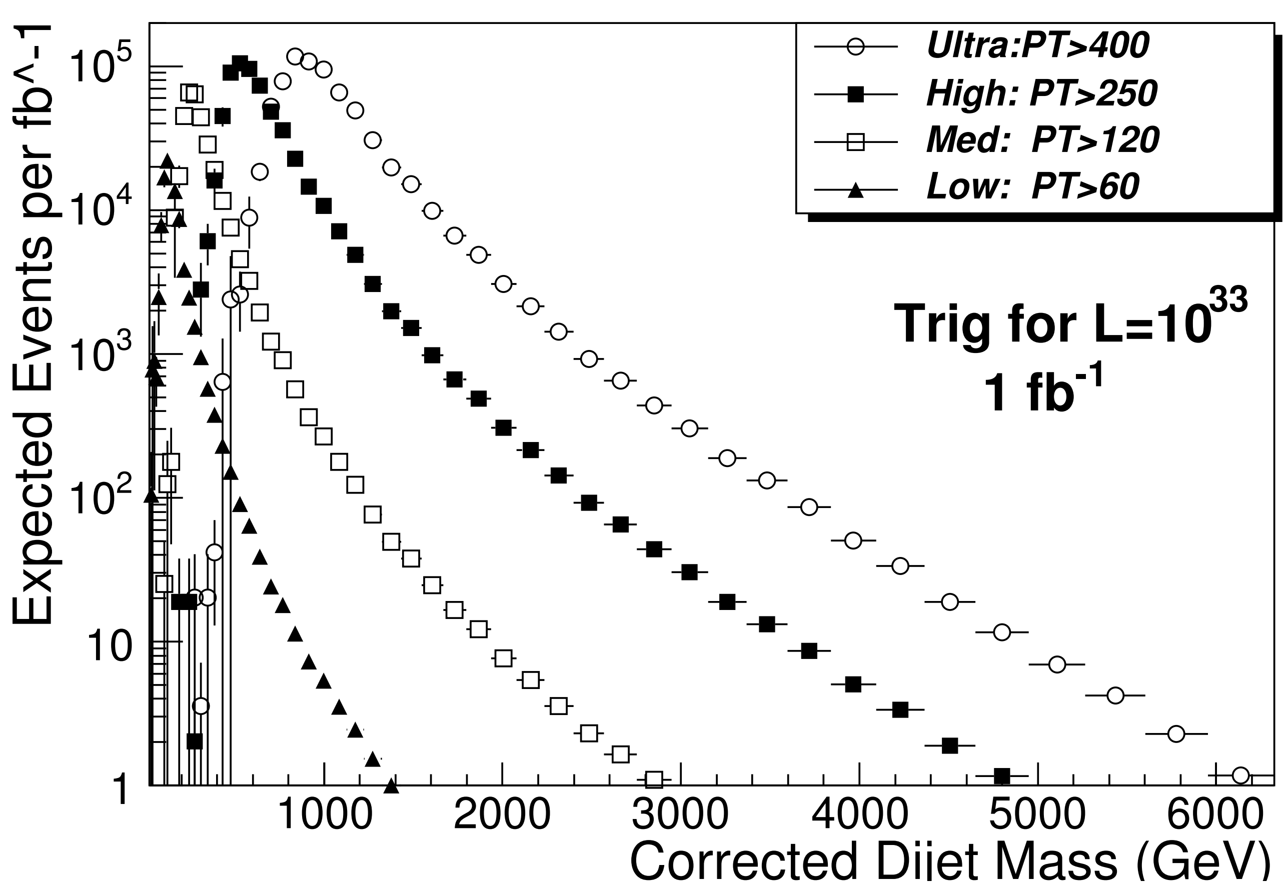
channel	Events
WZ	96.8
ZZ	5.2
ttbar	2.8
μμbb	11.4
eebb	3.0

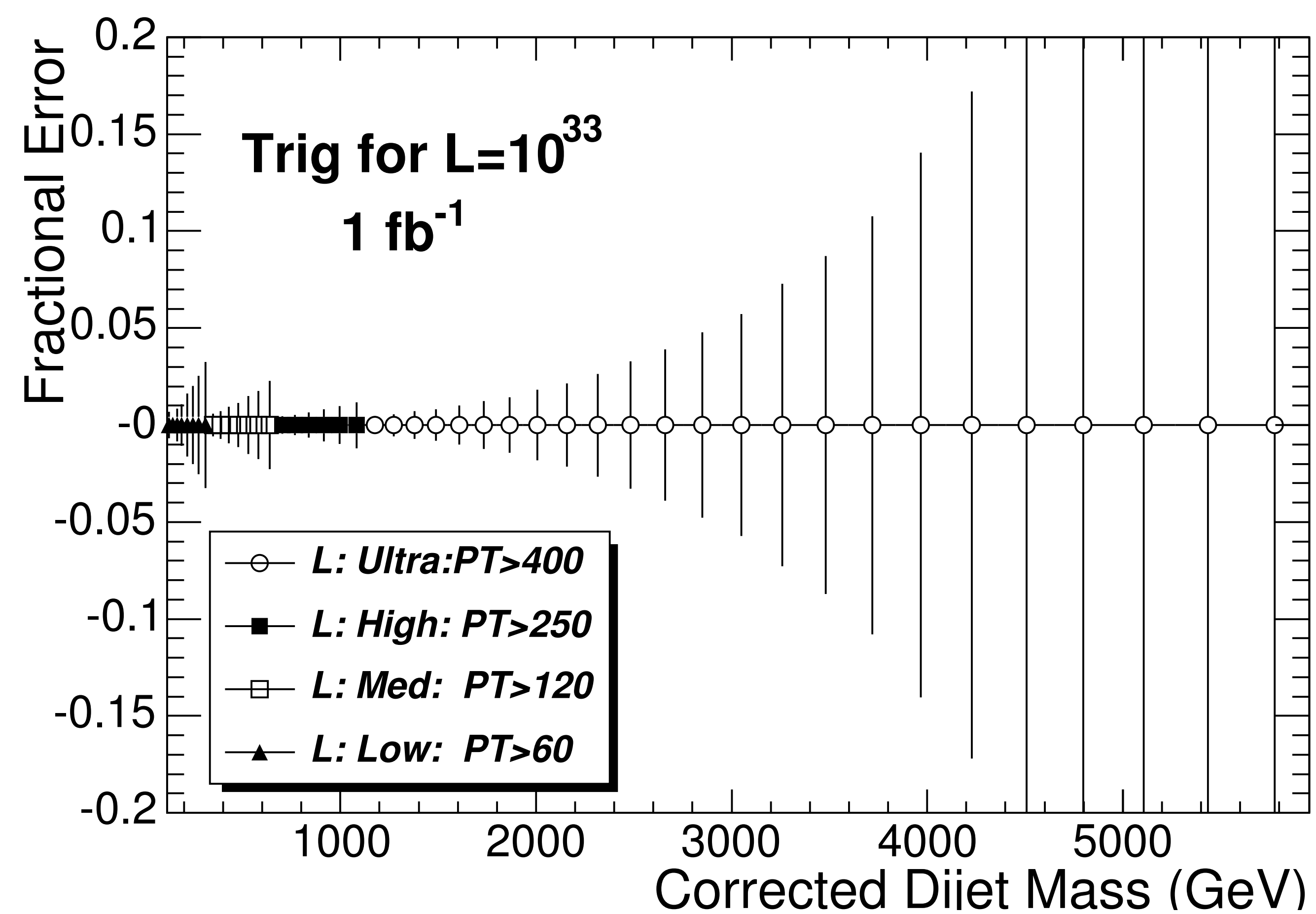


Dijet Analysis with 1 fb^{-1}

- Trigger strategy extended to "Ultra" high threshold to avoid prescale on highest threshold trigger

Statistical precision < 3% for dijet masses < ~2.5TeV





Using top for Jet Energy Scale

- Start with lepton + 4 jets events w/ tight kinematic selection
- Require exactly two b-tagged jets

  Remaining two jets should be from W

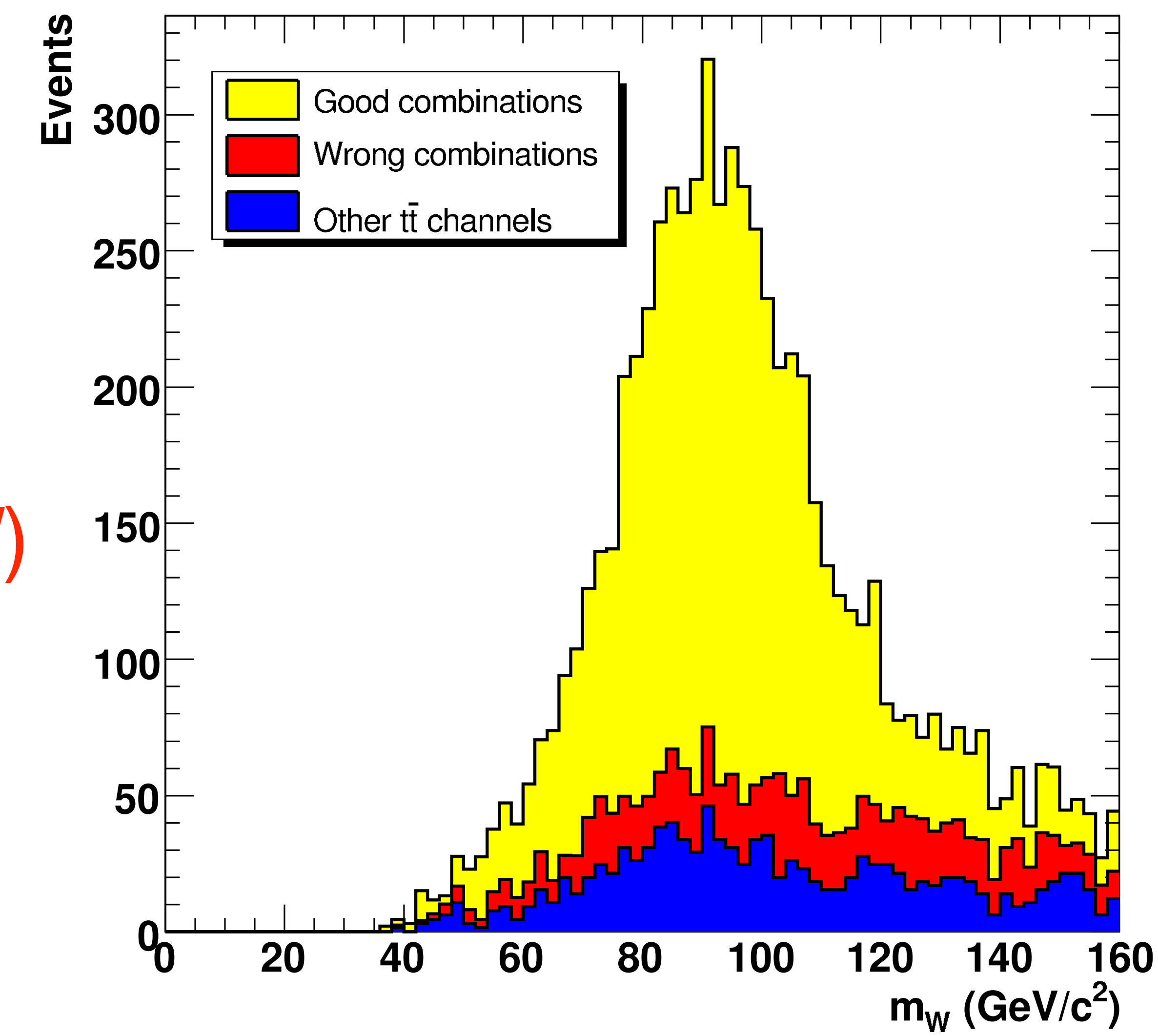
  Correct combination found with efficiency ~80%
- Further reduce background with cuts on $P_T(W)$ and m_{top}

  1 fb^{-1}: ~700 signal events

To obtain JES, rescale all jets by $(1+\Delta C)$ to obtain new m(W) distribution

Get ΔC from best fit to PDG m(W)

Similar procedure using m(W) and m(top) can be used for b-jets

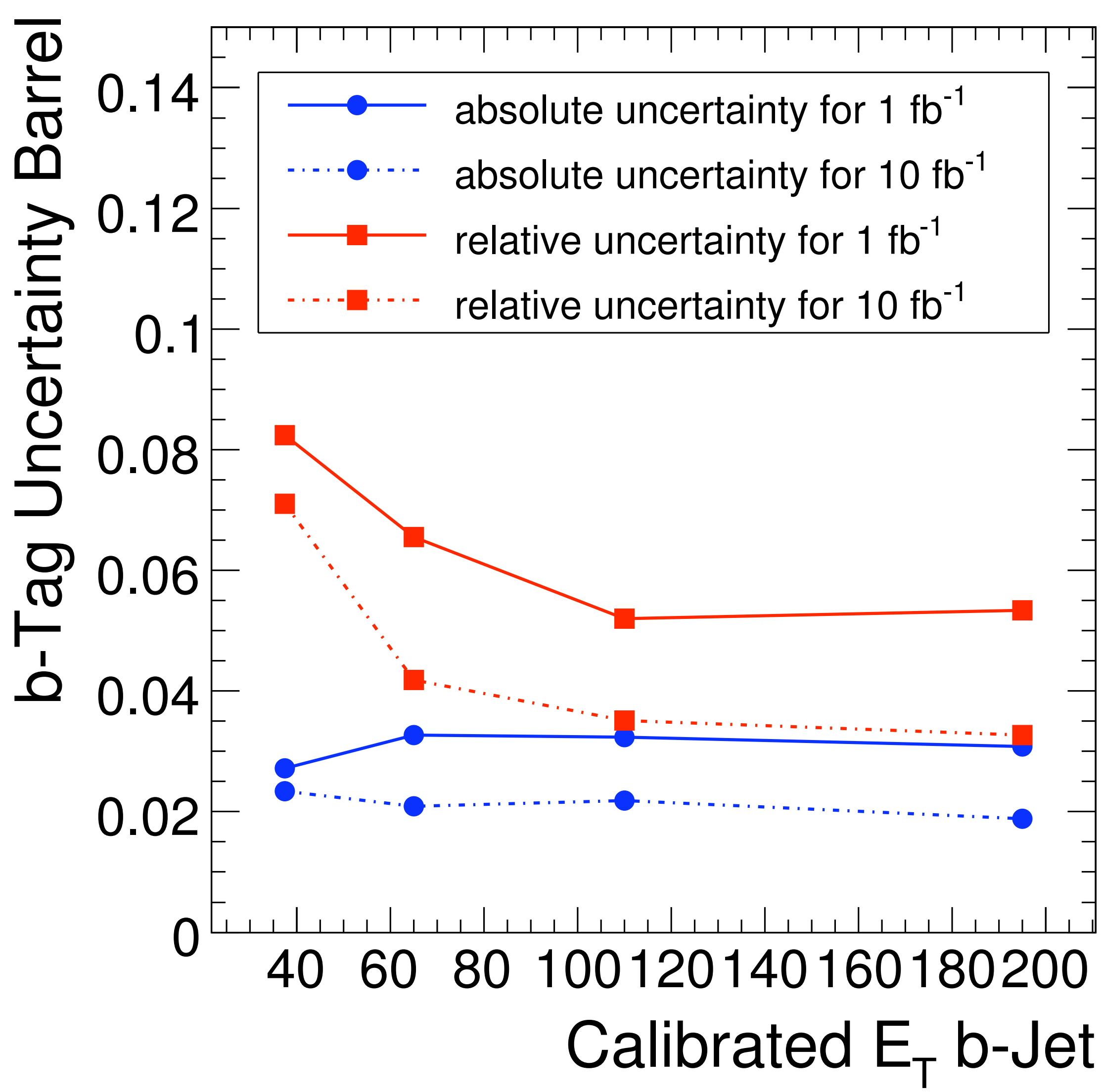


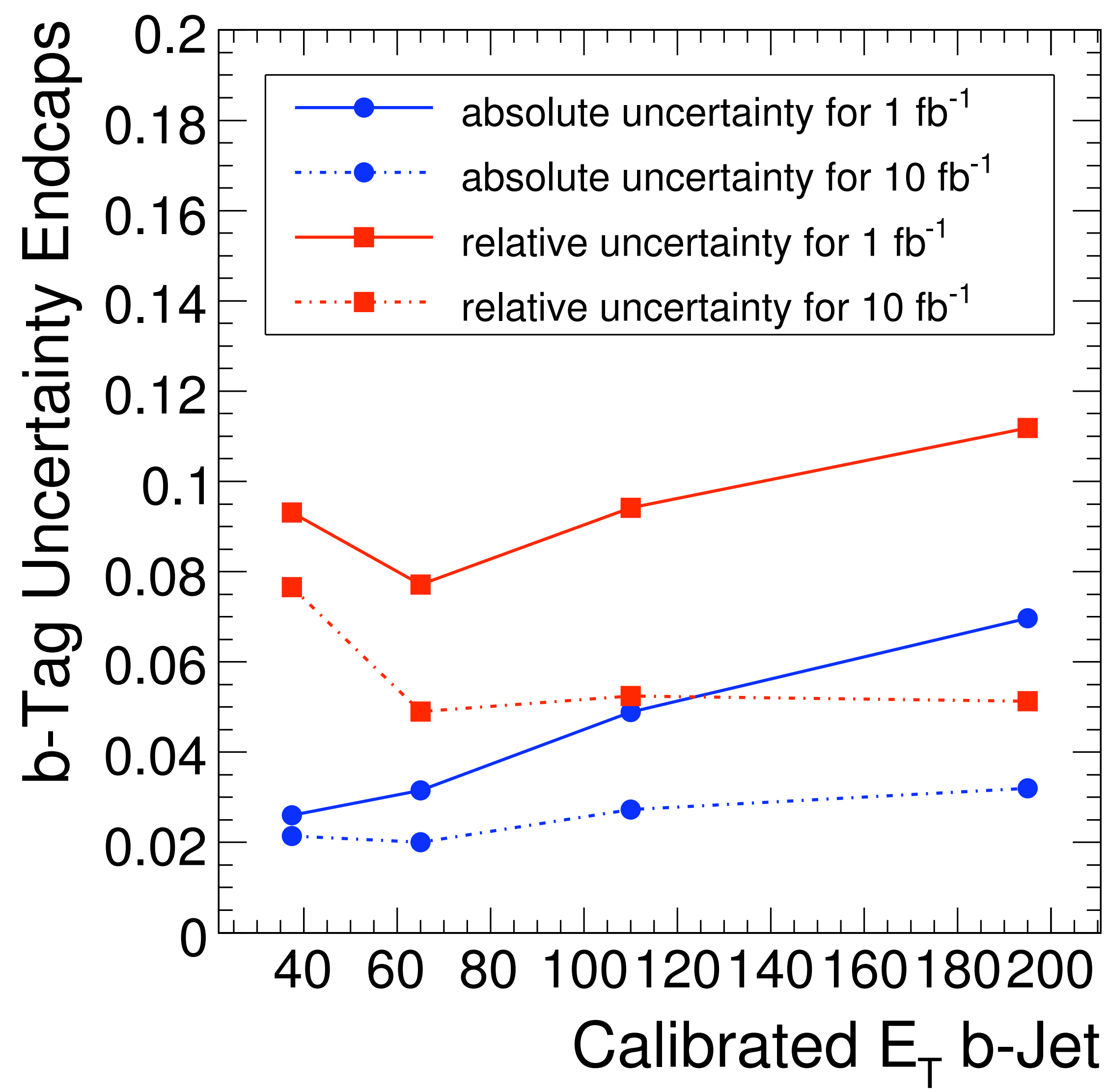
Measure b-tag efficiency in data

Tight kinematic requirements to optimize efficiency for choosing correct jet pairing

Yields pure b-jet sample to measure tagging efficiency

(Important for any later H→bb search)





Activities at the LPC

Many experts resident at the LPC

- Simulation: Daniel Elvira, Harry Cheung
- Jets, Missing E_T: Rob Harris, Marek Zielinski
- Electrons, photons: Yuri Gershtein, Colin Jessop, Jeff Berryhill
- Muons: Eric James, Michael Schmitt
- Tracking: Kevin Burkett, Steve Wagner
- Trigger: Kaori Maeshima, Greg Landsberg
- Taus: Alexei Safonov
- b-tagging: Cecilia Gerber, Meena Narain
- Physics: Boaz Klima
- Offline Software: Liz Sexton-Kennedy
- Plus many detector experts as well

Activities at the LPC

Physics activities still ramping up

Next Friday, Saturday : Mini-Workshop on Early CMS Physics

Friday:

- Discussion of CMS plans for physics
- Discussion of common areas of interest

Saturday:

- Tutorials to get people going with analysis

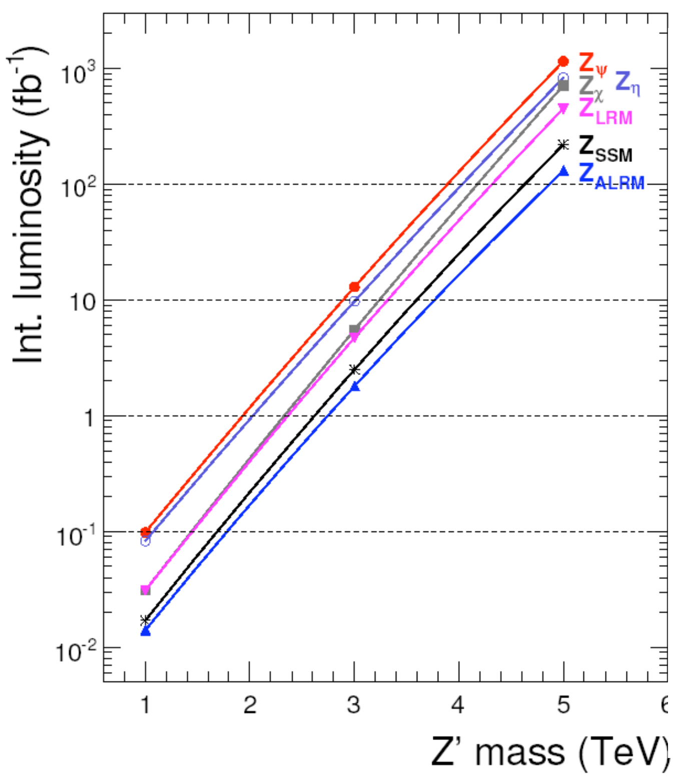
http://www.uscms.org/LPC/lpc_wkshp/early_physics_jun07.html

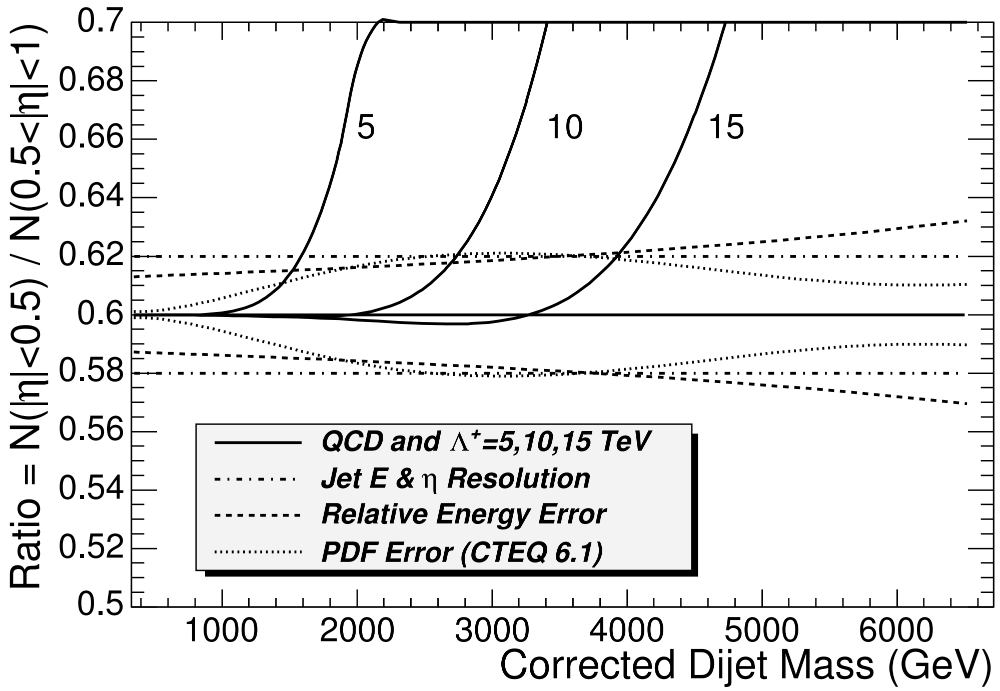
Conclusions (I)

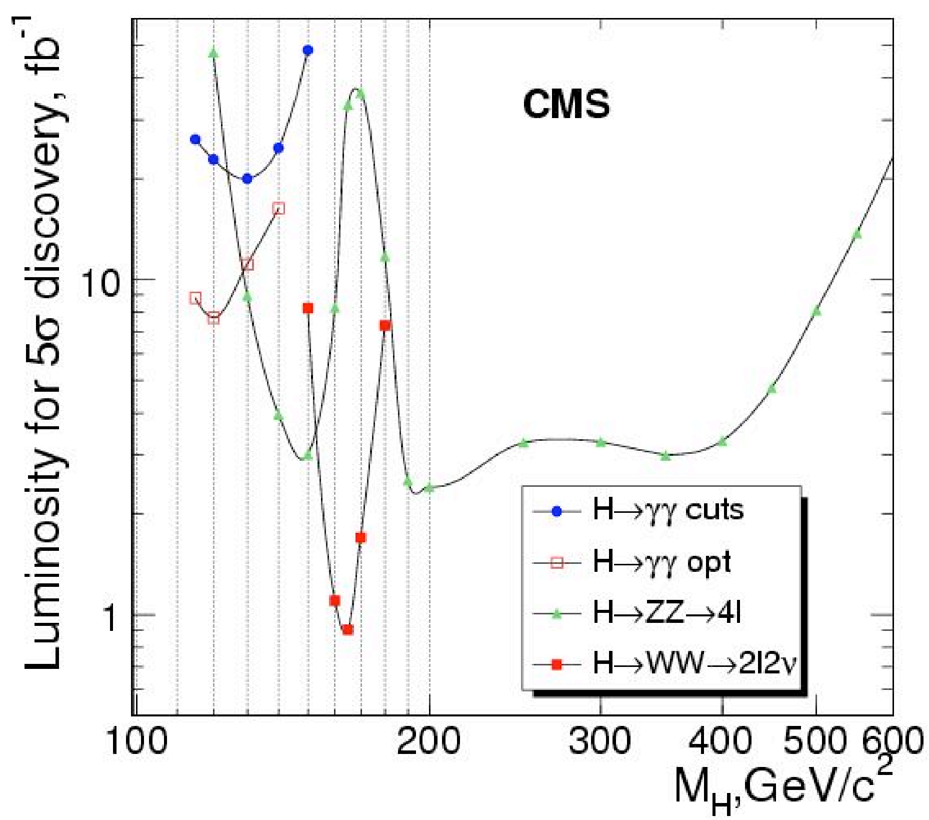
- LHC offers the possibility of exciting discoveries
- Lots of work ahead to prepare, but we should be able to use clear SM signals in the commissioning
- Some milestones along the way
  - With 10 pb^{-1}
    - Measure W and Z cross-sections
    - Observe top production
  - With 100 pb^{-1}
    - Measure top production
  - Measurements with 1 fb^{-1} should go beyond the current Tevatron precision

Conclusions (II)

If we have done a good job, then with 1 fb^{-1} of data we might see something new







Thanks to J. D'Hondt, R. Tenchini, D. Green, J. Incandela, and A. De Roeck, from whom I have borrowed material